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How to assess sustainability transformations: a review

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Review Paper

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Non-technical summary

There is a call to change societies to become more sustainable. We examine how the concept of sustainability transformation has been used and find that it has been defined in many ways. The concept is still used without many real-world examples – we found only four studies that had assessed whether a multi-sectoral sustainability transformation had taken place. There is a need to further clarify what sustainability transformation means and how it can be assessed.

Technical summary

A transformation towards sustainability is increasingly called for as a future vision for society, and simultaneously this has grown in importance as a research topic. We undertook a systematic literature review of multi-sectoral sustainability transformation studies to see whether researchers assess sustainability transformations empirically and how they do so. Unsurprisingly, there are many definitions of sustainability transformation, as well as many scales on which it has been studied. The concept was often used only as a metaphor without empirical grounding, and the process of the transformation towards the intended end result – sustainability – was seldom defined. These findings are also supported by previous research. We found only four empirical cases that assessed whether a sustainability transformation had taken place, and an additional 12 articles that had partially assessed for a fundamental transformation. Multiple methods to assess transformation were used, as well as various approaches to account for temporal dynamics of change and spatial focuses. It appears that, despite the increasing rhetoric for multi-sectoral sustainability transformations, this concept has not yet sparked wide efforts by academics to assess them empirically. These findings demonstrate the need to advance the debate regarding the methods for capturing these complex social phenomena.

Social media summary

A review of sustainability transformations shows the challenges of assessing change and the need to focus on methods.

1. Introduction

The need for a fundamental transformation towards sustainability has been expressed within the scientific community for some time (Meadows *et al.*, 1972; Rees, 1995) and has increasingly been proposed as a practical future vision for society, as current development trajectories challenge living conditions for humanity (IPBES, 2019). As these calls have increased, so have questions of what is meant by a sustainability transformation, whether these transformation processes can be observed empirically and with what methods (Patterson *et al.*, 2017). Sustainability transformations as a research topic has grown in importance (Patterson *et al.*, 2017; Pereira *et al.*, 2015; Schäpke *et al.*, 2015). To contribute to the field, we systematically review the academic literature and examine empirical examples of fundamental multi-sectoral transformation within sustainability research.

While sustainability transformation as a concept is relatively new, it builds on the long tradition of research in different fields that focuses on social and environmental change, driven by the need to address wicked global problems, such as food insecurity, climate change, biodiversity loss and persistent poverty (Dentoni & Bitzer, 2015; Levin *et al.*, 2012). As a result, multiple conceptual definitions (Feola, 2015) and approaches (Caniglia *et al.*, 2017; Sengers *et al.*, 2019) have emerged. This is not necessarily problematic (Etzion *et al.*, 2017), as there will always be multiple ways of conceptualizing a social phenomenon. What is of special interest to us is how the concept of sustainability transformations is operationalized in empirical articles and what research methods are used to study them. This is necessary to further our knowledge of transformations and can enable the realization of transformations as more becomes

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known about how they take place. This focus sets our study apart from these existing publications, as no systematic review of methods analysing sustainability transformations has been published. We also argue that a focus on operationalization is crucial to understanding whether these transformations are taking place and, if so, where, at what pace and how they are occurring, so as to improve our scientific understanding of them. A systematic review can be a first step in this direction, followed by, for example, studies comparing different methods and using methodological triangulation.

Sustainability transformation brings together two concepts: sustainability and transformation. Both concepts present unique circumstances regarding their definitions and use, as well as their assessment. On the one hand, sustainability is defined as dynamic stability in social and ecological systems and their interactions. However, several dimensions of sustainability are often misunderstood (Vogt & Weber, 2019). The concept of sustainability originates from the most commonly used definition of sustainable development, which states that we should meet the needs of the present human population without compromising the ability of future generations to meet their own needs (United Nations World Commission on Environment and Development, 1987). Social sustainability has been assessed, for example, using the Human Development Index (United Nations Development Programme, 1990) and, more recently, with the Sustainable Development Goals (United Nations, 2015). Environmental sustainability has been assessed in different ways, such as with the ecological footprint and ecosystem services approaches.

On the other hand, transformation can be defined as a process of change that fundamentally alters interactions and feedback processes between society and the environment (Walker *et al.*, 2004). For example, the Global Assessment Report on Biodiversity and Ecosystem Services states that the sustainability goals for 2030 and beyond may only be achieved through transformative changes, meaning fundamental, system-wide reorganization across technological, economic and social factors (IPBES, 2019). As noted by Feola (2015), societal transformation in response to environmental change has been studied in many scholarly traditions with a plurality of meanings. In his literature review,[i] he found that the most frequently used approaches to studying transformation were: deliberate transformation, progressive transformation, regime shift (resilience), societal transition (transition theory), social practices, transformational adaptation and socioecological transition. In addition, the idea of sustainability leverage points (Meadows, 1999) has frequently been used to study sustainability change. The concepts of transformation and transition are both used in studying sustainability change, often as synonyms. However, one way to separate the concepts is that a transition can be understood as a gradual process of change, which does not have to be dramatic (Geels, 2002), whereas a transformation would mean fundamental change. Such explicit distinctions between various concepts help us to understand the nuances between their interpretations. Interpretation of the change process can influence the methodological approach and types of methods chosen to study this change.

Considered together, sustainability transformation is still a relatively new concept that needs closer examination, particularly in terms of how it is operationalized. Hence, our aim with this article is to advance the discussion on how to assess sustainability transformations. Patterson *et al.* (2017, p. 2) note that studies "place an explicit focus on the processes of change in human society involved in moving towards more sustainable and equitable futures, which can be approached in both a normative way (e.g., as a good/desirable thing to do), as well as an analytical way (e.g., what actually 'happens', and how and why)."

In this review, we contribute to the transformations literature by systematically reviewing multi-sectoral sustainability transformation studies to see whether and how they assess sustainability transformations and to synthesizing the findings to map out future research questions. We have chosen to focus on multi-sectoral transformations because the calls for a fundamental transformation require that sustainability changes in one sector do not cause negative spill-overs to other sectors or other dimensions of sustainability.

When a sustainability transformation is to be considered as an empirical phenomenon, it needs to have a dimension of time and space and it has to be observable. As a social phenomenon, a sustainability transformation takes place across scales of social organization (Cash *et al.*, 2006), depending on the approach one adopts. These scales can be, for example, individuals and/or collective social units (O'Brien, 2012) or the scales of the multi-level perspective framework – niche, regime and landscape (Geels, 2002). So far, there have been no systematic reviews of empirical cases, nor has knowledge been acquired on how these transformation studies account for different scales: temporal, spatial or social. We are interested in the methods used in empirical articles in particular. We chose this focus on operationalization specifically to see what methods are used to assess fundamental social change in the academic literature. Assessing the multidimensional phenomenon of sustainability transformation is challenging. A focus on scientific methods to assess the change is important, because with many coexisting ways to understand it, empirical assessments may lead to the use of simple metrics that are neither significant nor consistent with the intended meaning. To structure our analysis, we pose the following research questions:

- What has been studied as a fundamental multi-sectoral sustainability transformation?
- On what scales are sustainability transformations studied?
- What methods have been or could be used to study sustainability transformations empirically?
- Have sustainability transformations taken place?

2. Materials and methods

Systematic reviews have become common tools to capture how rapidly moving fields of study develop (Berrang-Ford *et al.*, 2015). We searched Web of Science (WoS) and Scopus using search term combinations for sustainability and transformation and their close synonyms in titles, in addition to assessment and its synonyms in titles, abstracts or keywords (Table 1 & Supplementary Material S1).

We retrieved 266 articles from WoS and 235 articles from Scopus published between 1990 and 2018 on 9 February 2018. After removing duplicates (129 articles) and articles that did not study sustainability transformation (20), the initial number of articles was 352. For the review, we selected articles in which the objective was either to assess a fundamental multi-sectoral sustainability transformation in response to global environmental problems or to discuss different assessment approaches. This selection was based on the title and abstract. We excluded articles that focused on sustainability science, education or sustainability of universities (35), change within companies and organizations (18), agriculture and food (44), energy (15) or forestry (9). We

Table 1. Search protocol.

	Scopus	Web of Science
Search terms	(TITLE (sustainability AND transformation) OR TITLE (transformation AND to AND sustainab*) OR TITLE (societal AND transformation AND sustainability) OR TITLE (fundamental AND societal AND shift AND sustainability) OR TITLE (sustainability AND change) AND TITLE-ABS-KEY (measure* OR assess* OR evaluate* OR monitor*))	TITLE: (sustainability transformation) OR TITLE: (transformation to sustainab*) OR TITLE: (societal transformation sustainability) OR TITLE: (fundamental societal shift sustainability) OR TITLE: (sustainability change) AND TOPIC[a]: (measure* OR assess* OR evaluate* OR monitor*)
Excluded fields	Medicine, biochemistry, genetics and molecular biology, nursing, health professions, immunology and microbiology	Medicine general internal, geography physical, public environmental occupational health, engineering electrical electronic, health care sciences services, meteorology atmospheric sciences, primary health care, health policy services, hospitality leisure sport tourism, remote sensing, biotechnology applied microbiology, mineralogy, mineralogy, chemistry inorganic nuclear, dentistry oral surgery medicine, engineering chemical, imaging science photographic technology, metallurgy metallurgical engineering, nuclear science technology, and nursing
Article types included	Article, review and article in press	Article and review

[a]Title, abstract, author keywords, Keywords Plus®.

Table 2. Analysis framework.

Research questions	Content
What has been studied as a fundamental multi-sectoral sustainability transformation?	Definition of sustainability and/or transformation and/or definition of sustainability transformation Theoretical origins Normative or analytical approach
On what scales are sustainability transformations studied?	Geographical scale and/or spatial focus (urban, rural) Scales of social organization Temporal scale
Which methods have been or could be used to study sustainability transformations empirically?	Methods and data Scope of assessment (transformation assessed comprehensively or partially) Measurability of sustainability transformation
Have sustainability transformations taken place?	Have articles identified existing sustainability transformations?

also excluded other articles that had a sectoral scope (201), including land use and land cover change, water, transport, fisheries, air quality, soil, climate change adaptation, building, tourism and change of individuals, as well as one editorial and several book chapters. These were excluded from our dataset because we aspired to review the multidimensional sustainability transformation studies given the calls for fundamental transformations (Sachs *et al.*, 2019) and the need to address wicked problems (Dentoni & Bitzer, 2015). This procedure produced 30 articles for detailed examination (Supplementary Material S2), published between 2001 and 2018 in 18 journals.

Our initial idea was to review original research articles that have assessed a sustainability transformation with empirical evidence, defined as articles that use qualitative or quantitative empirical data to describe or assess a sustainability transformation. Empirical cases are of special interest because many scholars in the sustainability science field have the normative aim of contributing to solving real-world problems, thus suggesting that empirical evidence would abound. Furthermore, the theoretical development of the field could be complemented by further development of research methods and understanding of complex social phenomena. We classified 16 articles as empirical among the articles we reviewed. However, because of this limited number of articles that fit our original scope of assessing sustainability transformation empirically, we decided not to exclude those theoretical articles that fitted our search protocol, and we also accepted secondary data, simulations and scenarios, as well as those articles that also included theoretical sections, for the review. By theoretical articles we mean articles in which the content is mainly theoretical or conceptual or that include a review of the literature, but that also discuss assessing or measuring transformations.

We analysed the content of the articles with reference to the research questions, described in the analysis framework (Table 2). For the first three research questions, we reviewed all 30 articles. We highlight those aspects that were the most relevant to the reviewed articles in this review. For the third question, we took a closer look at the 16 empirical articles. We further categorized empirical articles based on whether they assessed the transformation comprehensively or whether they assessed it partially. For the fourth question, we analysed the articles that had assessed or described sustainability transformation (i.e., the empirical articles).

3. Results

3.1. Definitions of sustainability transformation

The studies reviewed used heterogeneous definitions and theories in framing the questions, or focused on conceptual debate as the

main content. Not all articles used the exact concept of sustainability transformation: some used a synonym. For example, Ernst *et al.* (2016) use the term 'sustainable urban transformation', which they define as a subset of urban sustainability transitions. Several articles did not explicitly define what they mean by sustainability, and even fewer defined how they operationalize the concept of transformation as an empirically measurable phenomenon. Martínez *et al.* (2016), for example, define sustainability based on practical measures (i.e., sustainability prizes).

None of the articles stated that the current levels of natural resource use are sustainable. Both the social and biophysical dimensions of sustainability transformation were recognised, often with one emphasized more than the other. In general, discussions on environmental sustainability mainly consisted of naming one wicked problem (e.g., climate change; Princiotta & Loughlin, 2014); listing several wicked global environmental problems; adding smaller-scale problems to the list, such as deforestation and desertification (Pant *et al.*, 2015); explaining the threat of planetary boundaries being breached (Barau *et al.*, 2016); and highlighting the importance of securing ecosystem services (Chapin *et al.*, 2012). Social sustainability, on the other hand, was less frequently defined, but could be seen as having two main components: current and intergenerational global equity (Pickett *et al.*, 2013). Unsustainability dynamics were presented, for example, via the dominating impact of humanity on the global biophysical system (Olsson *et al.*, 2017), or by societal dynamics and power relations as drivers of the use of biophysical resources (Pichler *et al.*, 2017), or by increasing population levels and energy-intensive lifestyles (Princiotta & Loughlin, 2014). The dimensions of sustainability transformation studied in the articles reviewed varied greatly, including (but not exhaustively) processes of change, example sectors, lifestyles, design principles, technologies and quantifiable magnitudes of change.

Studies frequently referred to articles from two or more theoretical origins. Some papers combined social and economic elements with ecosystems (e.g., Olsson *et al.*, 2017). In general, the resilience approach emphasizes the connection between nature and society within the planetary safe operating space, whereas ecological limits are not as well incorporated into socio-technical transition approaches (Olsson *et al.*, 2014). Patterson *et al.* (2017) described how emerging hybrid narratives can define planetary boundaries as the ceiling and social boundaries as the foundation of sustainability transformation, referring to Leach *et al.* (2012, 2013). The social endpoint of a sustainability transformation is seemingly harder to define than the ecological endpoint, even though social aspects were often mentioned when the definition focused on ecological aspects. The definition of sustainable urban transformation in Ernst *et al.* (2016) focused on social aspects: processes of change, sustainable places and normative societal goals as components of sustainable urban transformation. The magnitude of the social aspects of sustainability challenges was often seen to be dependent on the chosen starting point, and sustainability was highlighted as having an unequal distribution and not being unambiguous (meaning the existence of plural sustainabilities) or being contested (e.g., Patterson *et al.*, 2017). Reaching a consensus on long-term sustainability goals among stakeholders is also one of the greatest challenges in practise (Chapin *et al.*, 2012).

The end goal of sustainability varied in its relation to the current economic system. Sustainability transformation discourses commonly criticize unlimited economic growth: for example, Beling *et al.* (2018, p. 306) argue that "the quest for unlimited growth as equated with progress is generally contested by all transformation discourses, as are Western materialism, anthropocentrism, the destruction of the commons, and blind faith in science and technology." In contrast, in studies that focus on local sub-city-level sustainability projects, economic development is a part of the definition of sustainability (Daneri *et al.*, 2015; Ernst *et al.*, 2016).

It was often difficult to separate all of the theoretical approaches to which the articles related. Justification for the selection of theories, if made explicit, was based on, for example, "prominent conceptual approaches" (Patterson *et al.*, 2017, p. 5) or "current visibility and their catalytic character in broader development-critical debates and networks" (Beling *et al.*, 2018, p. 305). Some articles compared theoretical approaches or combined concepts from different origins (e.g., see Beling *et al.*, 2018, human development, degrowth and *buen vivir*; see Olsson *et al.*, 2017, Anthropocene, social innovation and transformations to sustainability; and see Patterson *et al.*, 2017, socio-technical transitions, social-ecological systems, sustainability pathways and transformative adaptation). Frequently used approaches were socio-technical transitions and socio-ecological transformations, as well as leverage points (Abson *et al.*, 2017).

Like Patterson *et al.* (2017), we also observed a distinction between sustainability as a normative goal and as an observable phenomenon. For example, Fischer *et al.* (2011) take an approach that is more analytical than normative. However, most articles took a normative approach by stating that sustainability transformation is needed. Princiotta and Loughlin (2014), for example, state that preventing catastrophic climate change is a monumental challenge and fundamental changes in energy generation and use are necessary. Haberl *et al.* (2011) also argue that a new socio-metabolic regime is required. The normative element of the social dimension of sustainability is highlighted by Pickett *et al.* (2013), who state that "sustainability is a normative social goal, resulting from a civic dialog, and suggesting processes of change toward that goal." Real-life sustainability transformation experiments were often normative (Weiland *et al.*, 2017). Li (2009) states that transformation is inevitable because climate stabilization is not compatible with the growth requirement of capitalism.

Some articles listed success factors for a sustainability transformation. Krellenberg *et al.* (2016) argue that "it is the combination between political will and local, people-centred approaches that drives the success of urban sustainability transformations." Patterson *et al.* (2017, p. 4) further contend that "perhaps governance for sustainability transformations entails a dual focus on high-level, longer-term transformation combined with an honest recognition of the realities of near-term incrementalism at the same time. That is, a strategy of *incremental change with a transformative agenda*, where a normative focus on sustainability transformations helps to orient incremental efforts (such as policy change) within a broader narrative of transformative change."

Many of the articles reviewed presuppose that the intention of sustainability transformation studies is to contribute to the actual change, not only to study, assess or measure it. Patterson *et al.* (2017) question whether the notion of transformation is useful for steering transformation or could be better used to describe change *ex post*. Many of the articles advocate transdisciplinarity (in the sense of involving non-scientific actors; e.g., building transformative capacity, engaging stakeholders in research, etc.) as an approach to achieving transformation rather than as an approach for assessing whether transformation happens (Krellenberg *et al.*, 2016; Ritz *et al.*, 2001; Trencher *et al.*, 2013; Wolfram *et al.*, 2016).

3.2. Scales of sustainability transformations

In terms of the geographical scale, we noted, similarly to Beling *et al.* (2018), that transformation discourses envision a global-level change, whereas existing 'sustainable living' projects are typically local experiments. Global degradation of the environment is an aggregate of local or regional processes and can be reduced by transformations at these levels (Chapin *et al.*, 2012). In the empirical articles reviewed, the geographical scale varied from a part of a city, to an entire city, to the regional, multinational and global levels. Several articles had a specifically urban focus (e.g., Higgins, 2013; Krellenberg *et al.*, 2016). Some articles without an urban focus discussed aspects related to urbanization: for example, Chapin *et al.* (2012) discuss the implications of urbanization for residents' sense of place. Some of the empirical articles covered several locations or compared individual cases. For example, Fischer *et al.* (2011) study citizens' views on governance approaches to stimulate behavioural change in several European countries.

Interestingly, even when the cases were local, biophysical limitations were discussed at the planetary level, rather than at the scale of the study itself (Barau *et al.*, 2016). Olsson *et al.* (2014) question the connections between multiple levels, asking how niche experiments can have an impact at the scale of global challenges, and they see the possibility of answering these questions by combining transition management and resilience theory. Different theoretical approaches have different strengths and weaknesses in studying the scales of transformations. Pant *et al.* (2015) discuss how climate change adaptation scholars account for space and place in local contexts of developed as well as developing countries in more detail than transition scholars. They contend that transition scholars focus on examples from developed countries, which tend to be urban-centric, and examine long-term sectoral transitions that cross spatial boundaries.

The scale of social organization also features in a number of studies. Some interesting questions were raised as to whether pre-existing initiatives and institutions can steer transformations (Olsson *et al.*, 2017; Pichler *et al.*, 2017) and regarding the stability versus change of institutions (Abson *et al.*, 2017). Westley *et al.* (2011) consider innovations at multiple institutional scales and conclude that institutions are required to set the conditions for innovations to contribute to broad societal challenges.

Different theoretical approaches have different typical timescales (e.g., less than a decade for innovation; Olsson *et al.*, 2017). Transition and social-ecological system approaches take a conceptual orientation to trajectories of change over time: sustainability pathways and plural and emancipatory orientations in transformational adaptation (Patterson *et al.*, 2017). Weiser *et al.* (2017) propose a time ecology approach, because temporal dynamics are often not explicitly considered or conceptualized in sustainability transformation research, even though "transformation processes are understood to be context-specific developments that happen over a specific period of time" (Weiser *et al.*, 2017, p. 275). Patterson *et al.* (2017) discussed the challenges of identifying a start and an end point of a transformation.

The temporal scale of empirically assessed sustainability transformations varied between millennia, decades, years and weeks, and from historical perspectives to the current situation and future projections. The year 2050 was used as a cut-off for several simulations, whereas Harich (2010) used a relative time period of 500 years. Importantly, we found no empirical cases that measured the process of change over time explicitly. Articles did, however, present a time series (e.g., Higgins, 2013), descriptions of change over time (e.g., Haberl *et al.*, 2011) or projections into the future (e.g., Princiotta & Loughlin, 2014). While no articles assessed change over time, they nevertheless highlighted the importance of considering sufficiently long time periods, intergenerational timescales in policy and the durability needed for transformational innovations, as well as other aspects related to time. Many articles measuring or describing transformations naturally focused on the past (e.g., Ernst *et al.*, 2016; Martínez *et al.*, 2016), although there was also a view that transformation is ongoing (Burns, 2011).

3.3. Assessing sustainability transformations

Only four of the articles reviewed assessed sustainability transformation, and an additional 12 articles did this partially (Table 3). Both qualitative and quantitative assessments of the varying dimensions of sustainability transformation were used, and many articles used both. In addition, both comparative and similar cases were used. Those articles that had assessed sustainability transformation used the following methods: case studies (Ernst *et al.*, 2016; Martínez *et al.*, 2016), multiple case studies (Chapin *et al.*, 2012) and lifestyle archetypes coupled with ecological footprint analysis (Moore, 2015). In addition to the methods mentioned, articles that partly measured sustainability transformation used, for example, scenarios, narratives, quantitative reviews, macro-level empirical analyses, interviews and simulations. What had been assessed and what data were used varied from article to article (Table 3).

While we argue that the novelty of this article is to focus on the assessment of sustainability transformations, there were articles that questioned the rationality and measurability of a sustainability transformation altogether. For example, Schlaile *et al.* (2017) state that stakeholders have differing visions and expectations of a transformation. Patterson *et al.* (2017) question whether we can observe when transformations are occurring and reflect on the relationship between incremental change and longer-term transformation (meaning decades). Weiland *et al.* (2017, p. 32) specify that: "As no blueprint of a sustainable society exists … the challenge is to define the shape of a sustainable society (target knowledge), as well as the process of achieving it (transformation knowledge)." Similarly, Olsson *et al.* (2017) specifically state that scaling out, up (institutional structures and processes) and deep (values, beliefs, etc.) are all required for a transformation, and that these cannot only be measured numerically. However, system knowledge – the knowledge of the functioning and causal links within natural (or social) systems – is a common target of natural science (Weiland *et al.*, 2017).

Weiland *et al.* (2017) discuss characteristics of sustainability experiments, observing that social actors other than scientists often design and evaluate outcomes, and they note that, as a consequence, failure and unexpected outcomes are seldom addressed. Abson *et al.* (2017) propose a research agenda, namely the realms of deep leverage for sustainability transformation: restructure (institutions), reconnect (interaction between people and nature) and rethink. Several articles propose combining research traditions or research methodologies from at least two fields (Olsson *et al.*, 2014; Pichler *et al.*, 2017).

3.4. Have sustainability transformations taken place?

The 16 empirical articles identified signs of a sustainability transformation not happening, a level of deteriorating sustainability or

Table 3. Empirical articles reviewed and a summary of their content related to the first three research questions.

Article	Assesses/partially assesses sustainability transformation	What has been assessed	At what scales studied	Which methods and data used
Ernst *et al.* (2016) Sustainable urban transformation and sustainability transitions; conceptual framework and case study	Assesses	Processes of change, sustainable places, but also normative societal goals	Local (old port), urban, transition experiment/landscape, regime and niche, decades	Case study, qualitative, documents, secondary public sources and secondary data from published studies, validated by interviews with stakeholders from the municipality, private companies and knowledge institutions
Martínez *et al.* (2016) Revealing Curitiba's flawed sustainability: how discourse can prevent institutional change	Assesses	Sustainable city discourse, sustainability measured by focusing on green spaces, water bodies and public transportation	City, institutional change, decades	Case study, quantitative and qualitative, secondary sources and official data from environmental and urban planning institutions and media
Moore (2015) Ecological footprints and lifestyle archetypes: exploring dimensions of consumption and the transformation needed to achieve urban sustainability	Assesses	Lifestyles, consumption, quantitative dimensions of transformation needed to achieve urban sustainability	Several countries, average footprint and lifestyle archetype, ecological footprint analysis from 2007	Lifestyle archetypes coupled with ecological footprint analysis, quantitative and qualitative, literature of field data from several countries, WWF living-planet ecological footprint index
Chapin *et al.* (2012) Design principles for social-ecological transformation toward sustainability: lessons from New Zealand sense of place	Assesses	Design principles motivated by the sense of place	Four areas, rural, social-ecological systems, centuries	Four cases, New Zealand, participatory, qualitative, government research reports, newspaper accounts and other published information, some authors participated in each case
Sarkki *et al.* (2017) How pragmatism in environmental science and policy can undermine sustainability transformations: the case of marginalized mountain areas under climate and land-use change	Partially	Plausible futures of treeline ecosystems in Europe, role of pragmatism in scenario development and use	European treeline areas, rural, scenarios 2000–2050	Global change scenario, classes and European scenarios, downscaled using iterative and collaborative discussions with around 60 experts and using the drivers–pressures–state–impact–response framework, analysis of pragmatism, qualitative and quantitative
Barau *et al.* (2016) Environmental ethics and future-orientated transformation to sustainability in Sub-Saharan Africa	Partially	The prospects of environmental ethics, narratives as a vehicle for transformation to sustainability	Hausa-speaking areas in West Africa, time period not specified (stories known to those who have attended school in the last four to five decades)	Identified storylines, phrases, myths and local and indigenous knowledge, qualitative, books, supporting interviews, academic literature, previously undocumented narratives
Daneri *et al.* (2015) Students as change agents in a town-wide sustainability transformation: the Oberlin Project at Oberlin College	Partially	Ways in which students can serve as agents of change and research, impacts of multi-stakeholder partnerships	Town, project (town, stakeholders, college and students) less than 10 years	Case, qualitative, data selection is not explained
Princiotta and Loughlin (2014) Global climate change: the quantifiable sustainability challenge	Partially	Climate change-related technologies and practises	Global, developed and developing countries, example countries, global community, from decades to centuries (past and future)	Review, qualitative and quantitative, secondary data (e.g., scenarios, statistics, time series, reports, etc.)
Higgins (2013) From sustainable development to carbon control: urban transformation in Hong Kong and London	Partially	Magnitude of urban transformations	Two cities, urban, decades (past and future)	Two cases: London and Hong Kong, qualitative and quantitative, official documents and statistics

Pickett *et al.* (2013) Ecological science and transformation to the sustainable city	Partially	Variety of possible urban transformations, how ecological processes might contribute to urban sustainability	International, Global North and South, urban, urban systems, centuries	Development of cities and elements of change process to a sustainable city, qualitative, data selection not explained
Trencher *et al.* (2013) Co-creating sustainability: cross-sector university collaborations for driving sustainable urban transformations	Partially	University as a partner in co-creation for sustainability	Global, several geographical scales, urban, university partnerships with government, industry and civic organizations, from years to decades	Macro-level empirical analysis based upon 27 partnerships and micro-level study of two cases, qualitative, macro-level: documents, publications and personal communications with key persons; two cases: literature and semi-structured interviews with the initiators
Fischer *et al.* (2011) Energy use, climate change and folk psychology: does sustainability have a chance? Results from a qualitative study in five European countries	Partially	Views on governance approaches to stimulate behavioural change in the field of resource use, generalized characteristics of humankind	European, urban and rural, citizens (individuals and collectively), no specific time period, interviews in 2009	Interviews from five European countries, grounded iterative analysis, qualitative, 202 interviews
Burns (2011) The sustainability revolution: a societal paradigm shift – ethos, innovation, governance transformation	Partially	Emerging sustainability revolution	Global, multiple levels (e.g., governance), centuries	Descriptive, qualitative and quantitative, secondary data, time series
Haberl *et al.* (2011) A socio-metabolic transition towards sustainability? Challenges for another great transformation	Partially	Socio-metabolic regimes, resource use	Global, developing and developed countries, collective socio-ecological systems, millennia (human history)	Descriptive, qualitative and quantitative, secondary empirical data for global resource use (material and energy flows, land use)
Harich (2010) Change resistance as the crux of the environmental sustainability problem	Partially	Change resistance and achieving proper coupling	Global, human system, relative time of 500 years	Simulation model, process diagrams, qualitative and quantitative, qualitative model, relative values
Li (2009) Capitalism, climate change and the transition to sustainability: alternative scenarios for the US, China and the world	Partially	Climate change and capitalist system	Global but focus on the USA and China, centuries (past and future)	Descriptive, qualitative and quantitative, secondary data, time series and scenarios

WWF = World Wide Fund for Nature.

an ongoing sustainability transformation. Whether the articles had identified an existing sustainability transformation relates closely to how they had defined what a sustainability transformation is.

Ernst *et al.* (2016) found that sustainability was not achieved during a certain target period in Rijnhaven, The Netherlands. Existing discourses on sustainability can hide unsustainability problems and prevent institutional change, such as in the city of Curitiba in Brazil (Martinez *et al.*, 2016). Here, the authors explain that at least some level of sustainability had existed before the relative deterioration in Curitiba in the past.

Moore (2015) explains, for example, how much the average consumption in selected countries exceeds the global ecological carrying capacity and how large the transformations should be in different sectors in countries with different levels of resource use, quantitatively speaking. These sectors cover ecological footprint, carbon footprint, food, buildings, consumables, waste, transportation and water. Higgins (2013) states that "none of the proposed actions from Hong Kong and London amount to a radical ecological change but merely a shift towards refining existing lifestyles with renewable energy, waste management and waste reduction and re-use strategies." Fischer *et al.* (2011) explain possible reasons for this and potential solutions: their interviewees described the societal context in industrialized countries as consumption-orientated, individualized and globalized, which means that top-down approaches such as regulations, increased prices and educational campaigns organized by government to shape the behaviour of the younger generations were thought to work towards achieving societal change. However, Fischer *et al.* (2011) added that this might be a discursive strategy to defend one's own inaction.

There are no sustainable cities in the sense that they need resources and supporting ecological processes outside their borders, but a city can become more sustainable (Pickett *et al.*, 2013). Chapin *et al.* (2012) presented case studies from New Zealand, showing that potential or actual transition to a more sustainable situation was achieved by stewardship emerging from a strong sense of place. In general, achieving or assessing sustainability in many possible dimensions simultaneously proved to be difficult. In the Oberlin project, the achievement of a sustainability transformation revealed challenges in creating a greenbelt, as well as in spurring economic development, while success was achieved with regards to carbon neutrality commitments, increasing alternative energy sources and renewables and sustainability education (Daneri *et al.*, 2015). Notably, Burns (2011) argues that an organic sustainability revolution is already taking place at a moral–cognitive level, in practises and at an institutional level, and that it is visible in, for example, greener values, standards, practises and technologies – although it is yet to be seen whether this transformation is sufficiently rapid and comprehensive. Harich (2010) contends that sustainability science and practise have focused on coupling people with the environment, but the ultimate problem is resistance to change. Therefore, he argues that sustainability research should next focus on studying the dynamics of change, which is closely related to our interests in terms of understanding how transformative change can be captured.

4. Discussion

We reviewed the academic literature to study whether empirical articles have found traces of existing multi-sectoral sustainability transformations, as well as to discover what has been studied, across what scales and with which methods. The most surprising fact was how few empirical cases have studied a fundamental multi-sectoral sustainability transformation to begin with. In the articles reviewed, more focus was placed on current unsustainability rather than on what the transformation process to improve the situation is or would be. This might not be so surprising when one thinks of the variety of dimensions of human action that can be defined as unsustainable.

Like in Feola (2015), the studies in our sample used heterogeneous theories to conceptualize a transformation. Understanding the use of different approaches to study this issue can advance both the science and practice of sustainability transformations, even if no consensus over definitions is likely to emerge. Even though the transition and transformation literatures overlap, we argue that they also hold differences. Transformation, which was our focus, is about a dramatic change or metamorphosis, and this has not yet been a major focus in empirical research, despite the calls for such transformations. Our review found theoretical reflections on the need for fundamental change, but no studies had documented efforts where it might have been achieved.

Instead, we found that articles define sustainability rather than sustainability transformation. In sustainability definitions, biophysical sustainability boundaries were often defined, while social ones were reflexive in that they often lacked any specific metrics or targets. When sustainability transformation was assessed, it was defined as a process towards a more sustainable situation, but it was not compared to or considered as progress to a specified target over time. Only Moore (2015) quantified the change to achieve ecological sustainability in different sectors in countries with different lifestyles. Without specific targets or designated durations for a social change, anything could then be defined as a transformation. We argue that the concept of transition would be more suitable when used in this way, since the endpoint of a transformation should be fundamentally different from the starting point. Similarly to Feola (2015), we argue that not all social changes should be labelled as transformations.

Sustainability interventions can target tangible but weak leverage points of transformation (Abson *et al.*, 2017). The most powerful leverage points for sustainability are in the personal sphere (Abson *et al.*, 2017; Meadows, 1999; O'Brien, 2018), which was often included in the description of change in the reviewed articles. Meadows (1999) originally presented a classification of leverage points in which the highest leverage points lie in changing the paradigm of a system and the individual's ability to transcend paradigms, both of which refer to transformative changes in the personal sphere. According to O'Brien (2018), the changes taking place are most often measured within the practical sphere, such as through behavioural change and technical measures. While our literature review did not find many examples of this, perhaps the propensity to measure observable and tangible changes in the practical sphere occurs as a way to manage the difficulty and complexity of measuring subjective transformations, such as paradigm changes in the personal sphere.

The question of the relationship between and the embedded nature of individual and collective changes deserves more attention in sustainability transformation-orientated research, as individual change and collective change have traditionally been observed in parallel fields. However, these two are related, because a society reflects the consciousness of the individuals who form it. Even though our literature review did not capture these, efforts have emerged to examine the dynamics between individuals and

communities within fields that study sustainability: for example, practice theory has been used to study this in the context of consumption (Shove & Spurling, 2013). In addition, links between experiments and wide-scale transformation have also been objects of sustainability studies (Etzion *et al.*, 2017). Transitions studies (e.g., Geels, 2010) have been used to empirically study sectoral and organizational sustainability change. Studying sustainability transformation in smaller units, such as at the level of an organization or a single sector, can bring about important empirical insights into understanding multi-sectoral sustainability transformations. However, more empirical evidence is needed to establish when smaller-scale changes do account for a fundamental multi-sectoral transformations.

There were multiple articles with an urban focus, and the city was a common scale at which to study sustainability empirically (Daneri *et al.*, 2015; Higgins, 2013; Martinez *et al.*, 2016). Smaller areas and larger regions, several countries and the global scale were also used. The empirical studies often focused on one geographical level, even though the need for global, multi-scalar transformation was often stated. The importance of spatial dynamics was thus considered, but not assessed empirically. Because of the global nature of the sustainability problem, fundamental transformation inevitably covers multiple scales. Similarly, multiple dimensions of transformation are recognized, but not yet empirically well demonstrated. Because of the multi-sectoral and multi-scalar nature of our definition of transformation, it probably happens as a process, not at a single point in time. Several articles seem to have used decades as a timescale to study sustainability transformation (Ernst *et al.*, 2016; Higgins, 2013; Martínez *et al.*, 2016). Many described historical events (e.g., Chapin *et al.*, 2012; Pickett *et al.*, 2013), thus indicating that case studies with a historical lens may be able to capture the change taking place. In addition, measuring change could be conducted via longitudinal studies repeated at regular intervals, but we did not find such studies. Changes were presented by means of descriptive style, qualitative data, time series, statistics, scenarios and simulations, often with secondary data.

Feola (2015) states that problem-based research tends to end with a prescriptive outcome, whereas emergent transformation is associated with descriptive–analytical research. Because the different choices of theories and concepts are suitable for different study framings, and due to the fact that they have different strengths and weaknesses, it is not wise to recommend the use of only one or even a few of them. Instead, the selection of theories and concepts should be made and justified based on the research problem at hand. According to Feola (2015), important directions for future research will be to find creative and fruitful ways to foster a dialogue around the potential and complementarities of different concepts; namely, what concepts can be applied to studying different types of systems, what prescriptive assumptions inform them, what concepts connect with which research paradigm, and what processes of change are ruled out from the analysis if a particular concept of transformation is employed. Another important direction for future research will be to fuel the dialogue by testing different concepts and theories of transformation with more empirical research and with the use of different methods. The scientific fields engaged in this research have matured enough to start assessing sustainability transformations by using, for example, longitudinal datasets and comparative cases in different contexts. In addition, empirical cases could place research in the context of transformation process scales and nested systems.

Based on our analysis, sustainability transformation as an empirical phenomenon is not yet very visible in the academic literature. The limited number of empirical studies we identified does not allow us to further elaborate whether sustainability transformations are currently taking place. This is in contrast to Burns (2011), who argued that a sustainability transformation is already taking place. However, our definition of transformation is more comprehensive than that of Burns (2011). While we found that multiple methods, approaches and framings can be used to study transformation, we did not detect a pattern that would suggest that certain definitions, framings or approaches lend themselves to assessments or measurements more easily than others. This may be due to our search protocol and the small number of articles extracted, or because a consensus on definitions has yet to emerge, which may spark off further methodological developments towards metrics of transformations.

The small number of empirical cases is notable, raising further questions. Is it too difficult to assess a sustainability transformation when societal and environmental change is occurring in any case? How does one include and combine multiple dimensions of sustainability transformation, such as the free will of individuals and systemic change? Do researchers not consider it important to assess transformation because it is seen as a task for practical and political actors? In research, it is also possible that the development of frameworks or studying more specific and theory-based phenomena might be considered more rewarding, rather than assessing or evaluating change in an empirical case setting. Naturally, there is also the question of whether a sustainability transformation should be assessed at all. Measuring complex sustainability issues, such as climate change vulnerability, with simple metrics has been criticized (Hinkel, 2011) because the concept itself is socially constructed. Questions also remain regarding how to assess sustainability transformations if they have not previously occurred. We argue that a lack of critical discussion on frameworks, methods and operationalization of the concept may render sustainability transformations meaningless. Through academic debate, researchers can bring clarity to the discussion and make it more accessible to wider society. Thus, rather than arguing whether it should be measured, we propose that debate should focus on the different ways in which this could be done according to sound scientific practice.

The normativity of sustainability transformation studies is an interesting question with regards to the philosophy of science. We argue that even normative approaches to sustainability transformations can develop assessment methods to account for empirical developments. The calls for a collaborative, transdisciplinary approach seem to be key components of sustainability science in advocating for transformations (Krellenberg *et al.*, 2016; Ritz *et al.*, 2001; Trencher *et al.*, 2013; Wolfram *et al.*, 2016). Interestingly, this call for transdisciplinarity (e.g., Schäpke *et al.*, 2015) was not very visible in the articles we reviewed, being demonstrated by only a few of the articles studying living laboratories, sustainability interventions or experimentation approaches. One may speculate whether this is due to the fact that transdisciplinary co-production approaches and measurement-based exercises are not often used in the same studies due to disciplinary traditions.

Naturally, there are limitations to our study design that need to be considered. We did not use 'transition' as a search term (for a review of the sustainability transitions literature, see, e.g., Markard *et al.*, 2012) because we wanted to focus specifically on the sustainability transformations literature. Using a wider variety of search terms would have yielded a greater number of empirical studies for review

and would have enabled a more comprehensive understanding of the methods for studying change. However, in this study, we wanted to focus on sustainability transformations in a fundamental sense and how they have been evaluated empirically, particularly when the study fulfilled the requirements for multidimensionality and transformative change. Further reviews could potentially compare the empirical use of different concepts, including transitions.

It is clear that the methodologies of studying transformation are far from being settled, and there is an urgent need for further methodological development. Based on our findings, we propose further steps for research on assessing sustainability transformations, and with these suggestions we hope to ignite discussion on the methods for assessing sustainability transformations.

First, given the conceptual plurality in the field, it is important in any study to state clearly the definition of transformation, and not only of sustainability. This allows for a critical evaluation across different studies and aids in distinguishing between various orientations in studying transformations (e.g., identifying paradigmatic shifts when those occur), thus eventually driving the field forward. Second, epistemological and methodological clarity are crucial in examining multidimensional phenomena. This includes choosing the type of empirical assessment or measurement that is in line with the research questions and definitions. It may also include seeking transdisciplinary methods that can measure objective, practical changes as well as subjective, personal changes, in both individual and collective dimensions. Third, as social change is ubiquitous, it is important to pay attention to the temporal scale of the transformation process, especially when designing research approaches. Research approaches that focus on historical developments may yield insights that cannot be captured with more common case study approaches (Räsänen *et al.*, 2019), but may present challenges in data collection. Fourth, the tried-and-tested methods of many disciplines can be used to study sustainability transformations in empirical case studies. There is also an emergence of interdisciplinary and transdisciplinary co-productive methods, the use of which requires care in terms of ensuring ontological and epistemological coherence, as these may sometimes be contradictory. Finally, it is important to acknowledge that if one adopts a normative goal (i.e., the research aims to contribute to achieving transformations), then those who are partial to that change ought to be involved in defining what is desirable, and the research approach and outcomes should be negotiated with those who have a stake in the social change to be initiated.

5. Conclusions

This article pushes forward the study of sustainability transformations in reviewing articles of fundamental multi-sectoral sustainability transformation. Our review finds that only a few empirical studies of a sustainability transformation exist, and the details of these transformation processes are seldom defined compared to the desired result: sustainability. Multiple dimensions of transformation are recognized but not yet empirically well demonstrated. Various methods, approaches and framings can be used for studying transformation, as well as various approaches to the temporal dynamics of change and space. While conceptual and methodological advances are likely to contribute to more empirical cases in the future, it is important to make a distinction between incremental change and change that alters the fundamental properties of the system. Assessing sustainability transformation is a complex task and requires more focus on how to do it. We have taken a first step in consolidating efforts to date and raise some key areas for future study. It is apparent that the terms 'sustainability' and 'transformation' have arisen from the current situation of unsustainability, and there is a clear societal need to advance this field. This article intends to contribute to that refinement of the practice and assessment of sustainability transformation as an evident and important next step.

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Note

[i] Feola used Web of Science with the concepts of transform and environmental change, as well as transform and climate change, for publications in the social sciences between 1990 and 2013.

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